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Advanced programming of cardiac resynchronisation therapy under echocardiographic examination: is it feasible and efficient?

Zaawansowana optymalizacja parametrów stymulacji resynchronizującej pod kontrolą echokardiografii

Alicja Dąbrowska-Kugacka[1], Anna Faran[1], Ewa Lewicka[1], Piotr Niedoszytko[2], Filip M. Szymański[3], Grzegorz Raczak[1]

[1]Department of Cardiology and Electrotherapy, Medical University of Gdańsk, Gdańsk, Poland
[2]Department of Rehabilitation, Medical University of Gdańsk, Gdańsk, Poland
[3]Department of Cardiology, Medical University of Warsaw, Warsaw, Poland

Abstract

In patients with heart failure treated with cardiac resynchronisation therapy (CRT), proper programming of the device can enhance the benefits of stimulation. Nowadays, adjustment of atrio-ventricular delay (AVD) is usually guided by echocardiography and performed only in resting conditions. The issue of optimal CRT programming during exercise, and the decision regarding the use of rate-adaptive pacing and rate-adaptive AVD algorithm during CRT, are largely empirical. We present a case report, and we indicate that programming of rate-adaptive pacing and rate-adaptive AVD algorithm on the basis of extended echocardiographic evaluation can further benefit the individual patient.

Key words: cardiac resynchronisation therapy, atrio-ventricular delay, echocardiography, exercise, heart failure

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In patients with heart failure (HF) treated with cardiac resynchronisation therapy (CRT), proper programming of the device can enhance the benefits of stimulation [1]. Nowadays, adjustment of atrio-ventricular delay (AVD) and interventricular delays is usually guided by echocardiography and performed only in resting conditions. The issue of optimal CRT programming during exercise, and the decision regarding the use of rate-adaptive pacing and rate-adaptive AVD algorithm during CRT, are largely empirical. Rate-adaptive pacing is commonly used in pacemaker patients without HF, although there may be substantial differences within the CRT population. Additionally, rate-adaptive AVD function (AVD shortening in response to heart rate increase) is available in CRT devices, although there are no guidelines as to how it should be programmed. In the present case report, we indicate that programming of rate-adaptive pacing and rate-adaptive AVD algorithm on the basis of extended echocardiographic evaluation can further benefit the individual patient.

A 75 year-old male with ischaemic cardiomyopathy, left bundle branch block (QRS 150 ms), and chronic HF in NYHA class III on optimal medical treatment, was referred to our hospital for CRT implantation. During cardiopulmonary exercise treadmill test (CPET), marked chronotropic incompetence was observed (maximal heart rate 81 bpm), maximal oxygen uptake at anaerobic threshold (VO_2/AT) was 9 mL/kg/min, and ventilatory equivalent for carbon dioxide ($V'E/V'CO_2$) was 36.8. Echocardiography demonstrated increased left ventricular (LV) end-diastolic diameter (70 mm), depressed LV ejection fraction (20%), moderate mitral regurgitation, mild interventricular dyssynchrony (40 ms) and moderate intraventri-

Address for correspondence:
Alicja Dąbrowska-Kugacka, MD, Department of Cardiology and Electrotherapy Medical University of Gdańsk, ul. Dębinki 7, 80–211 Gdańsk, Poland, tel: +48 58 349 39 10, fax: +48 58 349 39 20, e-mail: adabrowska@gumed.edu.pl

cular dyssynchrony (septo-lateral delay of the peak of systolic S′ waves determined by tissue Doppler method was 100 ms, and the 'apical shuffle' phenomenon was present) [2]. Atrioventricular synchrony was preserved. The patient successfully underwent CRT implantation (Maximo II CRT-D, Medtronic) with leads placed in postero-lateral LV vein, right ventricular apex and right atrial appendage. The device was optimised under echocardiography. In resting conditions, the longest transmitral filling time without A wave truncation was 100 ms during atrial sensed (74 bpm), and 130 ms with atrial paced (80 bpm), rhythm [3]. The greatest aortic velocity time integral (VTI_{Ao}) was achieved with simultaneous left and right

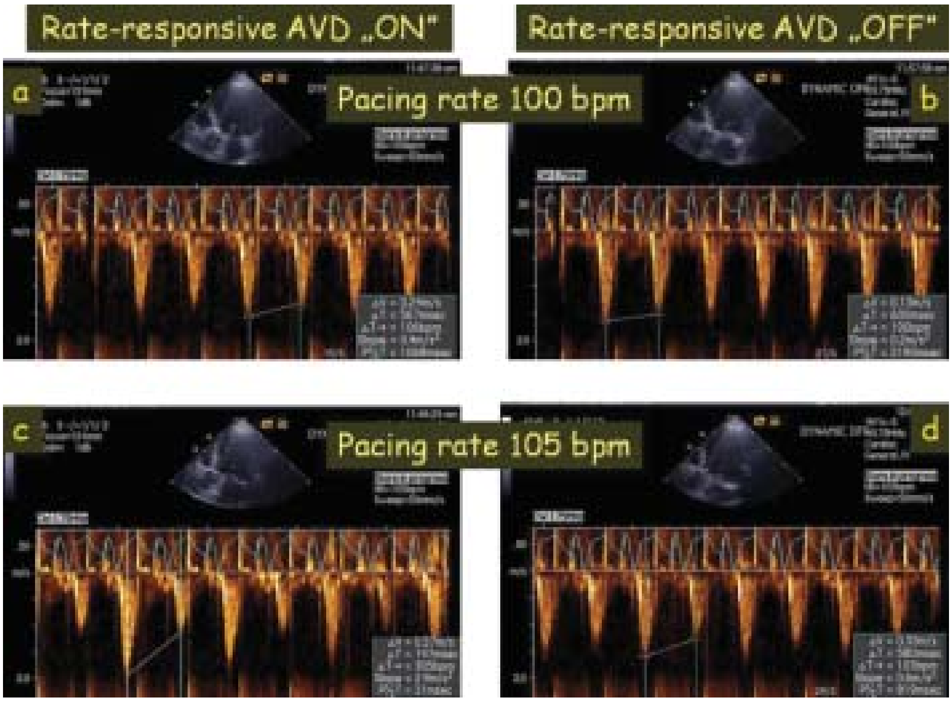

Figure 1. Aortic velocity time integral (VTI_{Ao}) registered by continuous-wave Doppler. Difference in peak velocity between consecutive beats (ΔV) at 100 bpm with rate-adaptive atrio-ventricular delay (AVD) function 'ON' equals 0.24 m/s (**A**), and 0.13 m/s with fixed rate-adaptive AVD (**B**). At atrial pacing rate 105 bpm, the difference is even higher: ΔV equals 0.57 m/s with rate-adaptive AVD function 'ON' (**C**) *vs* 0.33 m/s with fixed rate-adaptive AVD (**D**)

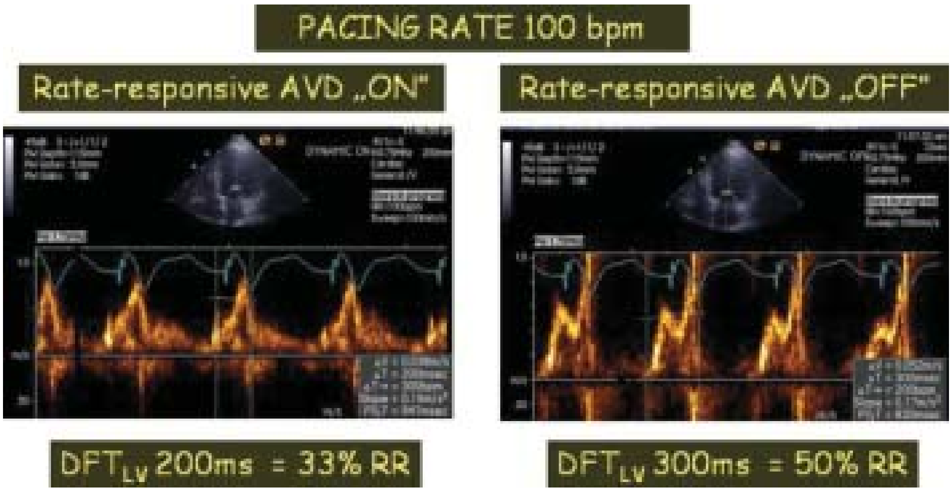

Figure 2. Mitral inflow at atrial pacing rate 100 bpm. **Left:** Rate-adaptive atrio-ventricular delay (AVD) function 'ON': fusion of the E and A waves is present and the diastolic filling time (DFT_{LV}) is markedly shorter (200 ms; 33% of the RR interval) compared to fixed rate-adaptive AVD (**right**): E and A waves are separated, longer DFT_{LV} (300 ms; 50% of the RR interval)

ventricular pacing. The interventricular delay was 30 ms, septo-lateral delay was 50 ms and the 'apical shuffle' phenomenon disappeared.

To determine the optimal upper limit of the rate responsive function VTI_{Ao} and mitral inflow were registered at increasing pacing rate 90, 95, 100, 105, 110 bpm, each lasting 2 min to ensure haemodynamic stabilisation of parameters. Evaluation was performed twice with rate-adaptive AVD switched 'ON' and 'OFF'. In both settings, pacing rate exceeding 100 bpm triggered alternating VTI_{Ao} velocities; however, with the rate-adaptive AVD 'ON', this phenomenon was observed at a lower pacing rate and was more prominent (Fig. 1). Additionally, during 100 bpm pacing with the rate-adaptive AVD 'ON', we observed fusion of the mitral E and A wave and marked shortening of the diastolic filling time (DFT_{LV}) (Fig. 2).

The patient underwent the CPET test with the CRT device programmed with: 1) standard settings (DDDR mode, lower rate 50/min, upper sensor rate 120 bpm, AVD 130/ /100 ms, rate-adaptive AVD algorithm 'ON'); and 2) optimal settings according to the echocardiographic evaluation (the only difference: upper sensor rate 100 bpm and fixed rate-adaptive AVD).

Biventricular capture was maintained during both CPET tests. Better results were achieved with the second settings: VO_2/AT 10 mL/kg/min, V'E/V'CO_2 35.1, peak exercise heart rate 100 bpm *vs* 9 mL/kg/min, 36.2 and 96 bpm, respectively, with standard pacing parameters. To judge which of the two settings is better in the daily life of a patient, we planned to programme the device for one month with the 'optimal settings' and then for one month with the 'standard settings' in a manner to which the patient was blinded. However, when the device was programmed in the second month with standard parameters, the patient came back to the outpatient clinic after three days due to shortness of breath on exercise.

DISCUSSION

There have been several reports suggesting that rate-adaptive pacing accompanied by rate-adaptive AVD improves exercise capacity in HF patients with marked chronotropic incompetence [4]. However, the optimal exercise programming of CRT devices has yet to be established. The upper rate limit in chronotropic incompetent subjects with CRT is established on the basis of age and concomitant diseases. It may have to be programmed lower to avoid ischaemia, impaired diastolic filling, and a blunted or inversed force–frequency relationship. In our patient aged 75 with ischaemic heart disease, the upper rate limit would have been programmed to about 80% (220–age), which gives a value of 116 bpm. In our patient, however, haemodynamic alternans of the VTI_{Ao} was observed with pacing rate exceeding 100 bpm. Haemodynamic alternans is attributed to changes in stroke volume with every other cardiac cycle, and it occurs most commonly in patients with severe LV systolic dysfunction [5]. When LV function is preserved, the increment in heart rate increases LV global contractility by the Treppe effect; however, in HF patients this effect can be blunted or even reversed [6]. Overdrive atrial pacing increases heart rate but results in shortening of ventricular filling, which may impede atrial contribution to stroke volume. Additionally, pacing from the right atrial appendage may influence intra- and interatrial conduction [7]. In our patient, deterioration in transaortic flow was observed at a relatively low pacing rate of 100 bpm, which constitutes only 69% of his age predicted heart rate. Haemodynamic alternans was accentuated and occurred at a lower pacing rate with the rate-adaptive function 'ON', with shortening of the DFT_{LV} and mitral A wave truncation. In Maximo II CRT-D (Medtronic) device, when rate-adaptive AVD function is programmed 'ON', a 10 ms AVD shortening at every 10 bpm increment in heart rate occurs between 80 and 120 bpm. Several investigations have confirmed that AVD on exercise is individual in each patient with HF: prolongation, shortening or no change of the resting AVD can be haemodynamically optimal [4]. The extrapolation of data obtained during incremental pacing without physiological exercise should be interpreted with caution, as in some patients adrenergic stimulation accelerates atrio-ventricular nodal conduction and the adaptation of AVD may be indispensible to maintain CRT during exercise. In our patient, biventricular pacing was maintained during both CPET tests, and the significance of echocardiographic optimisation was confirmed by CPET, as well as in the patient's daily life.

This case report confirms that programming of the CRT device under extended echocardiographic examination is feasible and can significantly benefit the individual patient.

Conflict of interest: *none declared*

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